1. **Tasks and problems of silo or bunker plants ("Diagnosis")**
   1.1 Components of material processing plant
   1.2 Tasks of material store
   1.3 Problems in silo or bunker plants ("Diagnosis")
1.1 Components of material processing plant

Block Flow Chart of Material Processing System

Balance boundary of material, energy, information and costs flows

[Diagram showing the flow of raw materials, auxiliary materials, information, energy, costs, store, recycling process, main product, by-product, waste, product formulation, store A, store B, store W, proceeds, information, energy, and proceeds.]
Multiscale Models of Dynamics of Particle Packings

1. **Continuum model**, \( \Delta V = \Delta x \cdot \Delta y \cdot \Delta z \)

   - tools:
     - mass (continuity),
     - force,
     - momentum (impulse),
     - moment (torque),
     - energy balances

   for translational and rotational degrees of freedom

2. **Particle interaction model**, \( dA = dx \cdot dy \)

3. **Molecular interaction model**

   fundamental material properties:
   - interaction energies,
   - potential forces,
   - elasticity,
   - bonding strength,
   - rate dependency,
   - electromagnetical, thermal and mechanical wave propagation characteristics,
   - phase conversion enthalpies etc.
Storage in Containers - Mechanical Behaviour of Solid, Liquid Gas and Bulk Solid

- a) parcel
- b) liquid
- c) gas
- d) bulk solid

with history

Kalman, H., Particle Technology in the Chemical Industry, Verfahrenstechnisches Kolloquium, Magdeburg 2002
<table>
<thead>
<tr>
<th>* Time consolidation or caking possible</th>
<th>1985</th>
<th>1986</th>
<th>1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>crude brown coal*</td>
<td>312</td>
<td>311</td>
<td>309</td>
</tr>
<tr>
<td>- powdered brown coal*</td>
<td>2,2</td>
<td>2,3</td>
<td>2,2</td>
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<tr>
<td>Grains *</td>
<td>11,6</td>
<td>11,7</td>
<td>11,2</td>
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<tr>
<td>- wheat *</td>
<td>4,0</td>
<td>4,2</td>
<td>4,0</td>
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<tr>
<td>- flour*</td>
<td>1,4</td>
<td>1,4</td>
<td>1,4</td>
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<tr>
<td>cement *</td>
<td>11,6</td>
<td>12,0</td>
<td>12,4</td>
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<tr>
<td>gravel</td>
<td>8,4</td>
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<tr>
<td>iron ore</td>
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<td>2,6</td>
<td>2,5</td>
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<td>lime *</td>
<td>3,6</td>
<td>3,6</td>
<td>3,6</td>
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<tr>
<td>Potassium fertilizers* K2O</td>
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<td>3,5</td>
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<tr>
<td>Nitrogen fertilizers N</td>
<td>1,1</td>
<td>1,3</td>
<td>1,3</td>
</tr>
</tbody>
</table>

in Mt

| sugar *                               | 911  | 935  | 895  |
| Soda *                                | 884  | 885  | 893  |
| Kaolin                                | 400  | 410  | 406  |
| Gypsum *                              | 312  | 305  | 299  |
| Phosphorous fertilizers * P2O5         | 299  | 309  | 291  |
| PVC                                   | 200  | 210  | 206  |
| Polyethylene *                        | 178  | 180  | 194  |
| Instant milk *                        | 173  | 176  | 171  |
| coffee                                | 60   | 62   | 63   |
| alumina * Al2O3                       | 47   | 47   | 51   |
| Instant drinking powders *            | 15   | 15   | 17   |

in kt
1.2 Tasks (objectives) of material store

Bunker or Silo Plant

process element at

- major plants
- minor plants
- auxiliary plants

main objectives

- technological store
  - different through put
  - different labour times
  - of pre-processes and successors

- trouble store
  - material flow disturbances
  - plant performance problems
  - increasing reliability

- blending of
  - material streams
  - particle size distributions
  - densities
  - chemical mineralogical composition
  - increasing product quality of particulate solids
1.3 Problems in silo or bunker plants (“Diagnosis”)
Flow of Particulate Solids in Bunkers and Flow Problems

Funnel or Core Flow

Mass Flow

Mass Flow with Funnel Flow Effect (Expanded Flow)

Numbers show the sequence of discharge of bulk layers

Channelling, Piping, Ratholing

Bridging, Arching
Mass Flow, Funnel Flow and Silo Problems

Figure 1a: Mass flow
Figure 1b: Funnel flow

Figure 2a: Arching
Figure 2b: Ratholing
Figure 2c: Segregation

Many thanks to: http://www.dietmar-schulze.de/storage.html
### 2D-DEM-Simulation of Mass Flow, Funnel Flow and Bridging

<table>
<thead>
<tr>
<th>Simulation with particle properties like:</th>
<th>Mass flow</th>
<th>Funnel flow</th>
<th>Arching in hopper, small bridge</th>
<th>Arching in hopper-shaft transition, large bridge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small adhesion, no friction</td>
<td>Mass flow</td>
<td>Funnel flow</td>
<td>Arching in hopper, small bridge</td>
<td>Arching in hopper-shaft transition, large bridge</td>
</tr>
<tr>
<td>No adhesion, clumps, rolling friction</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Adhesion, no friction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adhesion, friction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Mass flow**: http://www.mvt.ovgu.de/mvt_media/Vorlesungen/Lecture_SFPS/small_coh_no_fric_balls-p-1998.AVI
- **Funnel flow**: http://www.mvt.ovgu.de/mvt_media/Vorlesungen/Lecture_SFPS/no_coh_no_fric_balls-p-1938.AVI
- **Arching in hopper, small bridge**: http://www.mvt.ovgu.de/mvt_media/Vorlesungen/Lecture_SFPS/no_coh_fric_clumps_slow-p-1992.AVI
- **Arching in hopper-shaft transition, large bridge**: http://www.mvt.ovgu.de/mvt_media/Vorlesungen/Lecture_SFPS/coh_fric_balls_slow-p-1944.AVI
Silo problems

Bunker outlet opening (Potassium Salt Mine, Zielitz)
Figure 1.12

Widely Spread Residence Time Distribution

- **Storage Time too Large**: 
  - Time Consolidation Problems
  - Inflammation or Explosion Hazards
  - Deterioration Problems

- **Storage Time too Small**: 
  - Deaeration Problems
Discharging of Moist Fly Ash in a Railway Wagon (of a Brown Coal Power Station) on Open Pit Mine Deposit

Flowing (Transportation Time $t \approx 2$ h, Moisture $X_w = 18\%$):

Block Discharging (Transportation Time $t \approx 3$ h, $X_w = 18\%$):
Transport und Entleeren:

Figure 1.15

- Insufficient Level Control
- Overloading and Collapsing Hazards

Building
- Reinforced Concrete Silo
- Sheet Metal Silo

Discharge Device

Unsatisfactory Reliability